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For: Method of Producing a Spread Multi-filament Bundle and an  
Apparatus Used in the Same

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Sir:

Applicant respectfully submits English translations of the priority documents, Japanese Patent Application No. 2003-193895, filed on July 8, 2003 and Japanese Patent Application No. 2004-034778, filed on February 12, 2004. Certified copies of the priority documents have been filed in PCT/JP2004/010006.

It is respectfully requested that applicant be granted the benefit of the filing date of the foreign application and that receipt of this priority document be acknowledged in due course.

Respectfully submitted,

  
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(English Translation of Japanese Patent Application No. 2003-193895)

METHOD OF PRODUCING A SPREAD MULTI-FILAMENT BUNDLE AND AN APPARATUS USED IN THE SAME

WHAT IS CLAIMED IS:

1. Method of producing a spread multi-filament bundle comprising the steps of: feeding a multi-filament bundle unwound from a yarn supplier such as bobbin, cone and cheese; passing said bundle as fed through a plurality of fluid flowing portions disposed along a moving course of said bundle with said bundle supported in suspension on said respective fluid flowing portions to put a fluid into contact with said bundle in passage so as to bend said bundle towards a direction to which said fluid flows and to flow said fluid through an interstice formed between adjacent monofilaments of said bundle due to bonding between said monofilaments being slackened by fluidal resistance, wherein said bundle as widthwise spread by passing through a foremost one of said fluid flowing portions is passed through subsequent ones of said fluid flowing portions one after another so as to gradually enlarge contact area with said fluid, thereby, said bundle being widely spread in a progressive manner.

2. Method of producing a spread multi-filament bundle according to claim 1 wherein said bundle fed from said yarn supplier is locally and reciprocally pressed crosswise with regard to said moving course so as to subject said bundle in passage to fluctuation of a tensile force applied thereto alternatively and continuously between tension and relaxation and said bundle moving under said fluctuation is issued out to said fluid flowing portions.

3. Method of producing a spread multi-filament bundle according to claim 1 or 2 wherein linearly back-and-forth friction is provided at least to a spread bundle issued out from said fluid flowing portion disposed at farthest from said yarn supplier.

4. Method of producing a spread multi-filament bundle comprising the steps of: feeding a number of multi-filament

bundles from a creel provided with yarn suppliers such as bobbin, cone and cheese such that said bundles are lined in parallel and in the same plane; passing said respective bundles as fed through a plurality of fluid flowing portions disposed along a moving course of said bundles with said respective bundles supported in suspension on said respective fluid flowing portions to put a fluid into contact with said respective bundles in passage so as to bend said respective bundles in passage towards a direction to which said fluid flows and to flow said fluid through an interstice between adjacent monofilaments of said respective bundles due to bonding between said monofilaments being slackened by fluidal resistance so as to bring spreading action into effect on said respective bundles in passage, wherein contact area with said fluid is gradually enlarged at said fluid flowing portions disposed farther from said yarn supplier so as to further promote spreading operation on said respective bundles in passage, thereby, a spread multi-filament bundles sheet with fringe side monofilaments of any adjacent spread bundles tangentially aligned and said monofilaments as a whole uniformly distributed in density being produced.

5. Method of producing a spread multi-filament bundle according to claim 4 wherein said number of bundles as fed from said yarn suppliers such that said bundles are disposed in parallel and in the same plane are locally and reciprocally pressed crosswise with regard to said moving course so as to simultaneously subject said respective bundles in passage to fluctuation of said tensile force applied to said respective bundles alternatively and continuously between tension and relaxation and said respective bundles moving under said fluctuation are issued out to said fluid flowing portions.

6. Method of producing a spread multi-filament bundle according to claim 4 or 5 wherein linearly back-and-forth friction is provided widthwise with regard to at least respective spread bundles issued out from said fluid flowing portion disposed at farthest from said yarn suppliers.

7. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein a bending degree control bar is transversely provided in said respective fluid flowing portions, under which bar said respective bundles pass in contact with said fluid so that a minimum degree by which said respective bundles in passage bend does not become smaller than a predetermined level as restricted by said bar.

8. Method of producing a spread multi-filament bundle according to claim 7 wherein a middle portion of said bar diametrically bulges like an entasis.

9. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein said fluid generated in said respective fluid flowing portions is suction air stream.

10. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein said bundle whose monofilaments are bonded together with a resin based sizing agent is passed through said respective fluid flowing portions with said bundle in passage heated so as to soften said agent, thereby, said bundle being widthwise spread.

11. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein a prolonged aperture opened along said moving course is segmented into said respective fluid flowing portions and said respective bundles as fed from said respective yarn suppliers such that they are aligned in parallel and in the same plane are put into contact with said fluid upon passing through said respective fluid flowing portions so as to put spreading operation on said respective bundles into progress.

12. Method of producing a spread multi-filament bundle in any one of the preceding claims wherein a liquid is adopted for said fluid to contact with and spread said respective bundles and said liquid is circulated through said respective fluid flowing portions via respective circulation tubes so that said respective bundles in passage through said respective fluid flowing portions are subjected to fluidal resistance by said liquid, thereby, said respective bundles being widthwise

spread.

13. Apparatus for producing a spread multi-filament bundle comprising respective yarn suppliers such as bobbin, cone and cheese around which respective multi-filament bundles are wound; a multi-filament bundle supply mechanism to feed said respective bundles unwound from said respective yarn suppliers; and a fluid flowing spreader comprising a plurality of fluid flowing portions disposed along a moving course of said respective bundles as fed to put a fluid into contact with said respective bundles in passage crosswise with regard to said moving course with said respective bundles supported in suspension on said respective fluid flowing portions so as to bend said respective bundles in passage towards a direction to which said fluid flows, thereby, said respective bundles being widthwise spread.

14. Apparatus for producing a spread multi-filament bundle comprising a yarn supplier such as bobbin, cone and cheese around which a multi-filament bundle is wound; a multi-filament bundle supply mechanism to feed said bundle unwound from said yarn supplier; a fluid flowing spreader comprising a plurality of fluid flowing portions disposed along a moving course of said bundle as fed to put a fluid into contact with said bundle in passage crosswise with regard to said moving course with said bundle in passage supported in suspension on said respective fluid flowing portions so as to bend said bundle in passage towards a direction to which said fluid flows, thereby, said bundle being widthwise spread; a linearly pressing mechanism that is a transversely prolonged rod member disposed between said multi-filament supply mechanism and a foremost one of said fluid flowing portions to locally and reciprocally press said bundle as fed widthwise with regard to said moving course so as to simultaneously fluctuate a tensile force applied to said bundle in carriage alternatively between tension and relaxation; and a multi-filament bundle friction mechanism to reciprocally move back and forth widthwise with regard to said moving course in linear contact with said bundle in passage

through said respective fluid flowing portions so as to promote said bundle being widthwise spread.

15. Apparatus for producing a spread multi-filament bundle comprising a creel provided with a number of yarn suppliers such as bobbin, cone and cheese around which respective multi-filament bundles are wound; a multi-filament bundle supply mechanism to feed said respective bundles unwound from said respective yarn suppliers in parallel such that they are aligned in the same plane; a fluid flowing spreader comprising a plurality of fluid flowing portions disposed along a moving course of said respective bundles as fed to put a fluid into contact with said respective bundles in passage crosswise with regard to said moving course with said respective bundles in passage supported in suspension on said respective fluid flowing portions so as to bend said respective bundles in passage towards a direction to which said fluid flows, thereby, said respective bundles being widthwise spread in progress.

16. Apparatus for producing a spread multi-filament bundle comprising a creel provided with a number of yarn suppliers such as bobbin, cone and cheese around which respective multi-filament bundles are wound; a multi-filament bundle supply mechanism to feed said respective bundles unwound from said respective yarn suppliers in parallel such that they are aligned in the same plane; a fluid flowing spreader comprising a plurality of fluid flowing portions disposed along a moving course of said respective bundles as fed to put a fluid into contact with said respective bundles in passage crosswise with regard to said moving course with said respective bundles in passage supported in suspension on said respective fluid flowing portions so as to bend said respective bundles in passage towards a direction to which said fluid flows, thereby said respective bundles being widthwise spread; a linearly pressing mechanism that is a transversely prolonged rod member disposed between said multi-filament supply mechanism and a foremost one of said fluid flowing portions to locally and reciprocally press said respective bundles in passage as fed

in parallel with each other in the same plane with a same feeding speed from said respective yarn suppliers so as to simultaneously fluctuate a tensile force applied to said respective bundles in passage alternatively between tension and relaxation; and a multi-filament bundle friction mechanism to reciprocally move back and forth widthwise with regard to said moving course in linear contact with said respective bundles in passage through said respective fluid flowing portions so as to promote said respective bundles being widthwise spread.

17. Apparatus for producing a spread multi-filament bundle in any one of claims 13 through 16 wherein said multi-filament bundle supply mechanism includes a tensile force adjuster to keep said tensile force of said respective bundles unwound from said respective yarn suppliers constant.

18. Apparatus for producing a spread multi-filament bundle in any one of claims 13 through 17 wherein said fluid flowing spreader comprises a plurality of fluid flowing portions respectively provided with a suction aperture opened in the same plane along said moving course; and a suction pump engaged to a discharge side of said respective fluid flowing portions.

19. Apparatus for producing a spread multi-filament bundle in any one of claims 13 through 18 wherein a prolonged aperture opened along said moving course is segmented into said respective fluid flowing portions.

20. Apparatus for producing a spread multi-filament bundle in any one of claims 13 through 19 wherein said fluid flowing spreader is a type in which a liquid circulates through said respective fluid flowing portions via respective circulation tubes so as to contact with said respective bundles in passage through said respective fluid flowing portions.

(DETAILED DESCRIPTION OF THE INVENTION)

(0001)

(TECHNICAL FIELD)

The invention relates to an improvement on a technique of spreading a multi-filament bundle, in more details, pertaining to a method of producing a high-quality spread multi-filament

bundle and a spread multi-filament bundles sheet better in quality and an apparatus used in the same by making use of a fluid passing through adjacent monofilaments of an arbitrary number of multi-filament bundles respectively so as to efficiently spread the respective bundles widthwise.

(0002)

(PRIOR ART)

As well-known, in order to make products made from resin based complex materials such as FRTP (Fiber Reinforced Thermo plastic) products and FRP (Fiber Reinforced Plastic) products in which such fibers of higher strength as carbon fibers, glass fibers, ceramic fibers and aromatic polyamide fibers are adopted for matrix material, a high-quality and as widely spread as possible fibers bundle whose monofilaments are aligned in parallel and uniformly distributed in density is expected to be produced. Such thermoplastic resins as polypropylene, polyamide, polyether ketone, polyphenylene sulfide and polyether ether imide in a fused condition are of higher viscosity than that of such thermoset plastics as non-saturated polyester and epoxy resins prior to be cured, so that the impregnability of such thermoplastic resins as mentioned above with a fibers bundle adopted for matrix material is unsatisfactory. Then, such poor impregnability and the frequent occurrence of voids in an FRTP product in which resin is not completely impregnated with a matrix causes the mechanical strength of such product to be weakened, which results in the deterioration of the product quality.

(0003)

In order to make a thermoplastic resin of higher viscosity in a fused condition sufficiently impregnated with a fibers bundle adopted for a matrix material, it requires that the monofilaments of the fibers bundle be widthwise aligned in parallel with each other and be thinly and uniformly distributed in density. Under such circumstances, the subject inventors have proposed an invention entitled 'Method of producing a spread fibers bundles sheet and an apparatus used in the same'



registered under Japanese Patent No.3049225 (refer to Prior Reference 1) and an invention entitled 'Method of producing a spread multi-filament bundles sheet and an apparatus used in the same' registered under Japanese Patent No.3064019 (refer to Prior Reference 2), in which they succeed in the production of a spread fibers bundle whose monofilaments are widthwise aligned in parallel and thinly and uniformly distributed in density.

(0004)

(PRIOR REFERENCE 1)

Japanese Patent No.3049225 as published in a Gazette (refer to paragraph [0011] through [0014] and Figures 1 through 7)

(PRIOR REFERENCE 2)

Japanese Patent No.3064019 as published in a Gazette (refer to the fifth embodiment on page 8 and Figures 23 through 26)

(0005)

The spreading system in one unit of the above patents comprises a front feeder, a suction cavity, a back feeder and so forth for performing spreading operation by suction air stream, but provided that the monofilaments of a fibers bundle are more uniformly distributed in density and spread more thinly, it requires that such spreading system be consecutively disposed in series so as to gradually proceed with performing spreading operation on the fibers bundle, which makes an apparatus as a whole larger in scale. On the other hand, where a number of fibers bundles are disposed side by side to be spread so as to be produced into a widely spread fibers bundles sheet, the fringe side monofilaments of which adjacent bundles are overlapped one over another, such spreading system shall be disposed side by side, which makes an apparatus by far larger in scale and more complicated in structure.

(0006)

(ISSUES TO BE SOLVED)

In view of the inconveniences encountered with the prior

art as mentioned above, the invention is to provide a method of producing a spread multi-filament bundle and an apparatus used in the same whereby a high-quality spread multi-filament bundle and a multi-filament bundles sheet better in quality whose monofilaments are aligned in parallel and uniformly distributed in density are producible with high efficiency.  
(0007)

Further, the invention is to provide a method of producing a spread multi-filament bundle wide enough to be used for a reinforced material of an FRP or FRTP product and excellent in impregnability of resin enabling a fused thermoplastic resin of high viscosity to be smoothly and uniformly impregnated between adjacent monofilaments thereof and an apparatus used in the same.  
(0008)

Further, the invention is to provide a method of economically producing a spread multi-filament bundle and an apparatus used in the same whereby such multi-filament bundle as almost all kinds of the fibers of higher strength such as carbon fibers, glass fibers, ceramic fibers and aromatic polyamide fibers being bundled is spread in a space-saving and inexpensive manner so as to be produced into a spread multi-filament bundle larger in width.  
(0009)

(MEANS TO SOLVE THE ISSUES)

The methodical and mechanical means to solve the above issues are described below with reference to the accompanying drawings.  
(0010)

The method of producing a spread multi-filament bundle according to the invention comprises the steps of feeding a multi-filament bundle  $T_m$  unwound from a yarn supplier such as bobbin, cone and cheese; passing the bundle  $T_m$  as fed through a plurality of fluid flowing portions 31·32·33·34... disposed along a moving course of the bundle with the bundle supported in suspension on the respective fluid flowing portions to put

a fluid into contact with the bundle in passage so as to bend the bundle towards a direction to which the fluid flows and to flow the fluid through an interstice between adjacent monofilaments of the bundle which is formed by the bonding between adjacent monofilaments being slackened due to fluidal resistance, wherein the bundle  $T_m$  as spread at the fluid flowing portion 31 is passed through the subsequent fluid flowing portions respectively one by one so as to gradually enlarge contact area with the fluid, thereby, the bundle being widely spread in a progressive manner.

(0011)

Further, the method of producing a spread multi-filament bundle according to the invention comprises the steps of feeding in parallel a number of multi-filament bundles  $T_m$  in the same plane and with the same feeding speed from a creel 1 provided with a number of yarn suppliers 11 such as bobbin, cone and cheese; passing the respective bundles  $T_m$  as fed through a plurality of fluid flowing portions 31·32·33·34... disposed along a moving course of the respective bundles with the respective bundles supported in suspension on the respective fluid flowing portions to put a fluid into contact with the respective bundles in passage so as to bend the respective bundles towards a direction to which the fluid flows and to flow the fluid through an interstice between adjacent monofilament of the respective bundles so as to put spreading operation on the respective bundles into progress, wherein contact area with fluid is progressively enlarged through the fluid flowing portions disposed farther from the yarn suppliers so as to further promote the respective bundles being spread, thereby, the respective bundles being produced into a spread multi-filament bundles sheet  $T_w$ , the fringe side monofilaments of which adjacent bundles are tangentially aligned and the monofilaments of which as a whole are uniformly distributed in density.

(0012)

Then, the apparatus for producing a spread multi-filament

bundle according to the invention comprises a yarn supplier such as bobbin, cone and cheese around which a multi-filament bundle  $T_m$  is wound; a multi-filament bundle supply mechanism 2 to feed the bundle unwound from the yarn supplier 11; and a fluid flowing spreader 3 comprising a plurality of fluid flowing portions disposed along a moving course of the bundle as fed to put a fluid into contact crosswise with the bundle in passage with the bundle supported in suspension on the respective fluid flowing portions so as to spread the bundle with the bundle bent towards a direction to which the fluid flows.

(0013)

Further, the apparatus for producing a spread multi-filament bundle according to the invention comprises a creel 1 provided with a number of yarn suppliers 11 such as bobbin, cone and cheese; a multi-filament supply mechanism 2 to feed in parallel the respective bundles unwound from the respective yarn suppliers 11 in the same plane and with the same feeding speed; and a fluid flowing spreader 3 comprising a plurality of fluid flowing portions 31·32·33·34··· disposed along a moving course of the respective bundles to put a fluid into contact crosswise with the respective bundles in passage with the respective bundles supported in suspension on the respective fluid flowing portions so as to spread the respective bundles with the respective bundles bent towards a direction to which the fluid flows.

(0014)

Some technical features of the invention are followed up below.

- (1) Firstly, a fibers bundle that the invention is intended to cover is principally such multi-filament bundle as such conventionally well-known fibers of higher strength as a number of carbon fibers, glass fibers, ceramic fibers, polyoxymethylene fibers and aromatic polyamide fibers being bundled, which does not mean that such multi-filament bundle as a number of metallic fibers or synthetic fibers being bundled is excluded from the scope

of the invention, but the invention may also cover such multi-filament bundle as may be conceivable other than those mentioned above. The invention copes with performing spreading operation on both the sole fibers bundle and a number of fibers bundles.

- (2) The use of a fluid put into contact with a multi-filament bundle so as to spread the same includes such kinetic energy as gas flow such as air and steam, liquid flow such as water and other liquids and liquid-gas two phase flow.
- (3) The fluidal speed may be the same or vary in the respective fluid flowing portions. For instance, the fluidal speed of the respective fluid flowing portions may vary from higher to lower or vice versa, which speed is efficiently selected according to the state where the bundle is being spread.
- (4) Further commenting, upon a multi-filament bundle  $T_m$  passing over the respective fluid flowing portions disposed along the moving course of the bundle, it requires that the respective monofilaments of the bundle move widthwise with the bundle bent towards a direction to which the fluid flows so as to be spread. Thus, the tensile force applied to the bundle and the fluidal speed are determined in considerations of the physical properties and the feeding speed of the bundle in issue. Providing that the tensile force applied thereto is too strong or the fluidal speed is too slow, the bundle does not bend but just pass over the respective fluid flowing portions so as to prevent spreading operation from being effectively performed thereon.

(0015)

(EMBODIMENTS)

Hereafter, the preferred embodiments to carry out the invention are described in more details with reference to the accompanying drawings.

(0016)

(FIRST EMBODIMENT)

The method of producing a spread multi-filament bundle according to the present embodiment is explained below on the basis of an apparatus example as shown in Figures 1 and 2.  
(0017)

A multi-filament bundle having 5 mm in diameter and marketed under the item number of TR50S by Mitsubishi Rayon Co., Ltd., which bundle comprises 12,000 carbon monofilaments respectively having 7  $\mu$ m in diameter, as drawn out from the respective bobbins 11 by a multi-filament supply mechanism 2 is fed into a fluid flowing spreader 3 at the feeding speed of 10 m/minute upon passing through guide rollers 21 and 21.  
(0018)

The multi-filament bundle Tm as fed into the fluid flowing spreader 3 moves from an upstream side to a downstream side while crossing over in suspension an aperture of the respective fluid flowing portions 31·32·33·34 opened along the moving course of the bundle. The bundle Tm subjected to suction air stream during passing over the respective fluid flowing portions bends towards a direction to which the fluid flows so as to enlarge contact area with the suction air stream. The enlargement of such contact area allows the suction air stream to flow through an interstice between adjacent monofilaments of the bundle so as to slacken the bonding between them, which starts spreading the bundle. According as the bundle Tm moves from the foremost fluid flowing portion 31 via the portion 32 to the farther fluid flowing portion 33, it is gradually spread wider and wider and produced into a spread multi-filament bundle Tw having about 25 mm in width upon the passage of the farthest fluid flowing portion 34.

(0019)

(APPARATUS EXAMPLE 1)

Figures 1 and 2 show an apparatus used for the method of producing a spread multi-filament bundle according to the first embodiment.

(0020)

Reference numeral 1 therein indicates a bobbin adopted for

a yarn supplier, around which bobbin a multi-filament bundle Tm is wound.

(0021)

Reference numeral 2 therein indicates a multi-filament bundle supply mechanism, which supplier comprises guide rollers 21 and 21 to draw out and guide a multi-filament bundle Tm from the yarn supplier 11; support rollers 22 and 22 interposed between the guide rollers 21 and the yarn supplier 11 to support the bundle Tm as fed in a fixed position; and a tensile force adjustment damper 23 provided with a press roller 23a at its lower end portion and disposed between the anterior and posterior support rollers 22 and 22, which roller constantly abuts with the bundle as drawn out from the yarn supplier 11 under a certain pressure and presses the bundle Tm until the tensile force applied thereto becomes a predetermined level when such tensile force is rendered less than such predetermined level while the roller being bounced back by the tensile force applied to the bundle Tm to retract when such tensile force becomes more than such predetermined level. Upon the multi-filament bundle Tm passing through the guide rollers 21, the bundle Tm as issued out from the multi-filament supply mechanism 2 is fed into a fluid flowing spreader as described below under a certain tensile force applied thereto.

(0022)

Then, reference numeral 3 indicates a fluid flowing spreader of suction cavity tube type, which spreader comprises four fluid flowing portions 31·32·33·34 disposed in series. That is to say, the respective fluid flowing portions are disposed in the same elevation level along a moving course of the bundle Tm, on an entrance side and an exit side of which respective portions a guide roller 35 is provided to keep the elevation level of the bundle in passage constant. A suction pump 3a is engaged to the respective fluid flowing portions, the operation of which pump with a flow rate adjustment valve 3b regulated as necessary generates suction air stream with a flow rate required for the respective portions. The bundle Tm

passing over the respective fluid flowing portions is put into contact with the suction air so as to bend towards a direction to which the suction air flows and to flow the suction air through any adjacent monofilaments of the bundle, thereby, spreading action being brought into effect on the bundle in passage.

(0023)

Reference numeral 4 indicates a take-up roller to take up a spread multi-filament bundle Tw at a velocity of 10 m/minute after the passage of the respective fluid flowing portions, which spread bundle is wound up by a wind-up roller 5.

(0024)

(SECOND EMBODIMENT)

The method of producing a spread multi-filament bundle according to the present embodiment is explained below on the basis of an apparatus as shown in Figures 3 and 4.

(0025)

The respective multi-filament bundles Tm having 5mm in diameter and marketed under the item number of TR50S by Mitsubishi Rayon Co., Ltd. comprising 12,000 carbon monofilaments respectively having 7 $\mu$ m in diameter, as drawn out from the respective bobbins 11 by the respective multi-filament bundle suppliers 2 are aligned parallelwise in the same plane with an equal interval between them upon passing through the respective guide rollers 21 so as to be fed into the respective fluid flowing spreaders 3 with the same feeding speed.

(0026)

The respective bundles Tm as fed into the respective spreaders 3 move from an upstream side to a downstream side while crossing over in suspension an aperture of the respective fluid flowing portions in which suction air flows with a velocity of 20 m/second. The respective bundles Tm subjected to such suction air upon passing through the respective fluid flowing portions bend towards a direction to which the suction air flows so as to enlarge contact area with the suction air. The enlargement of such contact area causes the suction air to flow through an interstice between adjacent monofilaments of the respective



bundles so as to slacken the bonding between them, which starts spreading the respective bundles. According as the respective bundles move from the foremost fluid flowing portion 31 via the portions 32 and 33 to the farthest fluid flowing portion 34, they are gradually spread wider and wider and are produced into a spread multi-filament bundles sheet Tw having about 60 mm in width with the fringe side monofilaments of any adjacent spread bundles tangentially aligned after the passage of the farthest fluid flowing portion 34.

(0027)

(APPARATUS EXAMPLE 2)

Figures 3 and 4 show an apparatus used for the method of producing a spread multi-filament bundle according to the second embodiment.

(0028)

Reference numeral 1 indicates a creel provided with three yarn suppliers 11 of bobbin type, around which respective bobbins a multi-filament bundle Tm is wound. To note, only three yarn suppliers are shown, but the number of the bobbin may be modified with some other pegs not shown in the drawings in use where appropriate.

(0029)

Reference numeral 2 indicates a multi-filament bundle supply mechanism, which supplier comprises guide rollers 21 to draw out the respective bundles Tm from the respective yarn suppliers 11 and feed those bundles parallelwise in the same plane and with the same feeding speed; support rollers 22 and 22 interposed between the guide rollers 21 and the respective yarn suppliers 11 to support the respective bundles Tm as drawn out in a fixed position; and a tensile force adjustment damper provided with a rotatable press roller 23a at its lower end portion and disposed between the anterior and posterior support rollers 22 and 22, which roller constantly abuts with the respective bundles under a certain pressure and presses the respective bundles until the tensile force applied to the respective bundles becomes a predetermined level when such

tensile force is reduced less than such predetermined level while the roller 23a in abutment with the respective bundles is bounced back to retract when the tensile force applied to any one of the bundles is increased more than such predetermined level. The respective bundle  $T_m$  as issued out from the respective multi-filament suppliers 2 are aligned parallelwise in the same plane with an equal interval between them upon passing through the guide rollers 21 so as to be fed into the respective spreaders 3 under a certain tensile force applied to the respective bundles.

(0030)

Reference numeral 3 indicates a fluid flowing spreader of suction cavity tube type, which spreader comprises four fluid flowing portions 31·32·33·34 disposed in series. That is to say, the respective fluid flowing portions are disposed in the same elevation level along a moving course of the respective bundles, on an entrance side and an exit side of which respective portions a guide roller 35 is provided to keep the respective bundles in passage in a certain elevation level. A suction pump 3a is engaged to the respective fluid flowing portions, the operation of which pump with a flow rate adjustment valve 3b regulated as necessary generates suction air with a velocity as required for the respective fluid flowing portions. The respective bundle  $T_m$  passing over the respective fluid flowing portions are subjected to suction air flow so as to bend towards a direction to which such suction air flows and to flow such suction air through an interstice between adjacent monofilaments of the respective bundles, thereby, spreading action being brought into effect on the respective bundles in passage.

(0031)

Reference Numeral 4 indicates a take-up roller to take up a spread multi-filament bundles sheet  $T_w$  after the passage of the respective fluid flowing portions at a velocity of 10 m/minute, which spread bundle sheet is wound up by a wind-up roller 5.

(0032)

(APPARATUS EXAMPLE 3)

Figures 5 through 8 show an apparatus example 3 used for the method of producing a spread multi-filament bundle according to the second embodiment. The difference between the apparatus 3 and that 2 lies in the provision of a bending degree control bar 36 provided crosswise with regard to the moving course of the respective bundles in the respective fluid flowing portions 31·32·33·34, and the other structural arrangement thereof is the same as the latter. For the application of an apparatus example 3, the respective multi-filament bundles are put into contact with air flow with each of them passed under the respective bars, so that there is no case where the minimum degree by which the respective bundle moving through the respective fluid flowing portions bend does not become smaller than the predetermined level as controlled by the respective bars so as not to reduce contact area with the air flow, which improves the efficiency of the spreading operation performed on the respective bundles. The elevation level of the bar 36 may be modified vertically where appropriate by means of a well-known cross bar mechanism not shown in the drawings.

(0033)

Further commenting, the provision of the bending degree control bar 36 in the respective fluid flowing portions is arranged such that only the monofilaments located in the vicinity of both ends of the respective bundles in the process of being spread are put into contact with the respective bars while those located in the middle portion of each of them are drawn downwards and detached from the respective bars, as shown in Figure 8. Thus, there is no case where the monofilaments located in the middle portion of the respective spread bundles and those located in both ends of each of them during passing through the respective fluid flowing portions are inconsistent in length, which allows a spread multi-filament bundle whose monofilaments are uniformly distributed in density and that is larger in width to be produced.

(0034)

(APPARATUS EXAMPLE 4)

Figure 9 shows an apparatus example 4 used for the method of producing a spread multi-filament bundle according to the second embodiment. The difference between the apparatus example 4 and that 3 lies in the provision of a linearly pressing mechanism 6 of a back-and-forth press roller type disposed between the guide rollers 21 and the guide roller 35 provided on the entrance side of the foremost fluid flowing portion 31, and the other structural arrangement thereof is the same as the latter. The linearly pressing mechanism 6 adopted herein is a transversely prolonged rod member, which simultaneously fluctuates the tensile force applied to the respective bundles as fed parallelwise in the same plane and with the same feeding speed from the creel 1 alternatively between tension and relaxation by locally and reciprocally pressing the respective bundles in passage crosswise with regard to the moving course of the respective bundles. Upon the respective bundles in passage being linearly pressed and rubbed, the bonding between adjacent monofilaments of a locally pressed portion of the respective bundles is slackened while the tensile force applied to the respective bundles moving towards the respective fluid flowing portions fluctuates at certain timing between tension and relaxation in a continuous manner. The fluctuation of the tensile force applied to the respective bundles brings a fine spreading effect upon the respective bundles in passage being put into contact with the suction air flow in the respective fluid flowing portions. That is to say, when the tensile force applied to the respective bundles is in the relaxation mode, the respective bundles moving through the respective fluid flowing portions bend to large extent so as to enlarge contact area with the suction air, which promotes the respective bundles being further spread. According as the respective bundles move from the foremost fluid flowing portion to the farthest fluid flowing portion, the fluctuation of the tensile force applied to the respective bundles is leveled out, in which condition

the respective spread bundles are wound up by a wind-up beam 5.

(0035)

(APPARATUS EXAMPLE 5)

Figures 10 through 12 show an apparatus example 5 used for the method of producing a spread multi-filament bundle according to the second embodiment. The difference between the apparatus 5 and that 2 lies in the provision of a multi-filament bundle friction system M arranged such that the respective guide rollers 35 provided on an entrance side and an exit side of the respective fluid flowing portions to keep the respective bundles in a certain elevation level move back and forth widthwise with regard to the moving course of the respective bundles, and the other structural arrangement thereof is the same as the latter. That is to say, the respective guide rollers, as shown in Figures 10 through 12, are driven by a crank motor 35a through a crank arm 35b in engagement to a linkage system 35c. Upon the rotation of the motor 35a, the crank arm 35b converts such rotational motion into a back-and-forth motion, which motion is transmitted to the linkage system 35c so as to simultaneously move the respective guide rollers back and forth crosswise with regard to the moving course of the respective bundles. The monofilaments comprising the respective multi-filament bundles Tm moving in linear contact with the multi-filament bundle friction mechanism M of the apparatus example 5 frictionally slide widthwise by the action of the respective guide rollers 35 so as to render the fibrous bonding thereof slackened, which enhances the permeability of the suction air in the respective fluid flowing portions 31, 32, 33, 34 and 35, promoting the respective bundles being further spread.

(0036)

(APPARATUS EXAMPLE 6)

Figure 13 shows an apparatus example 6 used for the method of producing a spread multi-filament bundle according to the above second embodiment. The difference between the apparatus

example 6 and that 2 lies in the provision of a hot fan heater 7 oppositely disposed to the respective fluid flowing portions 31, 32, 33 and 34, and the other structural arrangement thereof is the same as the latter. This apparatus example 6 is particularly advantageous when the monofilament<sup>s</sup> comprising the respective bundles are bonded together with a synthetic resin based sizing agent. The sizing agent is softened in blowing hot air of 120 degrees Centigrade from the respective heaters over the respective bundles in passage, promoting the respective bundles being further spread along with the action by the suction air at the respective fluid flowing portions.

(0037)

#### (APPARATUS EXAMPLE 7)

Figure 14 shows an apparatus example 7 used for the method of producing a spread multi-filament bundle according to the above second embodiment. The difference between the apparatus example 7 and that 2 lies in that a prolonged aperture disposed along the moving course of the respective multi-filament bundles is segmented into the respective fluid flowing portions 31, 32, 33 and 34, and the other structural arrangement thereof is the same as the latter. In comparison with the latter, the former is done with the sole suction pump 3a and the sole fluid flow adjustment valve 3b so that the manufacturing cost of the apparatus is rendered inexpensive and the operation thereof is simplified.

(0038)

#### (APPARATUS EXAMPLE 8)

Figure 15 shows an apparatus example 8 used for the method of producing a spread multi-filament bundle according to the above second embodiment. The difference between the apparatus example 8 and that 7 lies in the provision of a bending degree control bar 36 in the respective fluid flowing portions 31 through 34, and the other structural arrangement thereof is the same as the latter. The action brought by the control bar 36 is the same as that of the apparatus example 3.

(0039)

(APPARATUS EXAMPLE 9)

Figure 16 shows an apparatus example 9 used for the method of producing a spread multi-filament bundle according to the above second embodiment. The difference between the apparatus example 9 and that 2 lies in the provision of a sealing plate 31a, 32a, 33a and 34a over the corresponding fluid flowing portions 31, 32, 33 and 34 such that a prolonged aperture disposed along the moving course of the respective bundles is opened widthwise to an extent corresponding to the spread width of the respective bundles in passage. The covering of such aperture with the sealing plates 31a, 32a, 33a and 34a prevents the energy loss of the suction air, which reduces the operation cost thereof.

(0040)

(THIRD EMBODIMENT)

The method of producing a spread multi-filament bundle according to the third embodiment is explained on the basis of an apparatus example 10 as shown in Figure 17.

(0041)

The respective multi-filament bundles  $T_m$  comprising 12,000 carbon monofilaments each of 7  $\mu\text{m}$  in diameter and having 5 mm in diameter and marketed under the item number of TR50S by Mitsubishi Rayon Co., Ltd. as drawn out from the respective bobbins 11 by the multi-filament bundle supplier 2 are aligned parallelwise in the same plane with an equal interval between them upon passing through the guide rollers 21 so as to be fed into the fluid flowing spreader 3 with the same velocity.

(0042)

Upon the respective bundles being fed into the fluid flowing spreader 3, each of them passes through in succession a waterproof tube of the respective fluid flowing portions 31 through 34 via watertight yarn holes  $h$ , through which tube hot water of 80 degrees Centigrade flows at the flow rate of 5 m/second. The respective bundles in passage engaged in contact with such hot water bend towards the direction to which such water flows so as to gradually enlarge contact area with such

hot water flow. According as such contact area enlarges, hot water flows through adjacent monofilaments of the respective bundles so as to slacken the bonding between the adjoining monofilaments that starts spreading the respective bundles. According as the respective bundles move from the foremost fluid flowing portion 31 via the fluid flowing portion 32 to the fluid flowing portions 33, each of them is gradually widthwise spread. Upon the respective bundles in the process of being spread passing through the farthest fluid flowing portion 34, a widely spread multi-filament bundles sheet Tw having about 75 mm in width with the fringe side monofilaments of any adjacent spread bundles tangentially aligned side by side is obtained.

(0043)

(APPARATUS EXAMPLE 10)

Figure 17 shows an apparatus example 10 used for the method of producing a spread multi-filament bundle according to the above third embodiment. Reference numeral 1 in the drawing indicates a creel, to which three yarn suppliers of bobbin type are suspended, around which bobbins respectively a multi-filament bundle Tm is wound. Reference numeral 2 indicates a multi-filament bundle supplier, which supplier comprises guide rollers 21 to draw out and feed the respective multi-filament bundles Tm from the respective yarn suppliers 11 parallelwise in the same plane; a pair of anterior and posterior support rollers 22 and 22 intervening between the guide rollers 21 and the respective yarn suppliers 11 to keep the respective multi-filament bundles as drawn out in a fixed position and a damper member disposed between the adjoining support rollers 22 and 22 and provided with a rotatable press roller 23a at its lower end portion. The arrangement of the creel 1 and the multi-filament bundle supplier 2 hereof respectively is the same as that of the apparatus example 2.

(0044)

Reference numeral 3 in the drawing indicates a fluid flowing spreader of water circulation type. Four fluid flowing portions 31 through 34 respectively of diametrically enlarged



waterproof tube type, through which portions respectively yarn passage holes h are provided, is adopted for the fluid flowing spreader 3. That is to say, the fluid flowing portions 31 through 34 respectively are provided with yarn passage holes h in the same elevation level along the feeding course of the respective bundles Tm. On an entrance side and an exit side of which fluid flowing portions respectively where a yarn passage hole h is opened, a watertight rubber guide roller 35 is provided to keep the respective bundles in passage in a certain elevation level. A circulation pump 3a is engaged to the respective fluid flowing portions, the operation of which pump with the flow rate of hot water regulated with a flow rate adjustment valve 3b causes hot water to circulate with a flow rate required for the respective fluid flowing portions via a circulation pipe 3c, whereupon the respective bundles passing through the yarn passage holes h of the respective fluid flowing portions bend towards the direction to which the circulating water flows in the meantime hot water flows through any adjacent monofilaments of the respective bundles, which brings spreading action into effect. (0045)

Take-up rollers 4 are disposed on the exit side of the farthest fluid flowing portion 34, by means of which rollers the respective widely spread multi-filament bundles Tw as discharged from the yarn passage hole h of the portion 34 are taken up at the take-up speed of 10 m/minute so as to be wound around a wind-up beam 5. To note, reference numeral 8 in the drawing indicates a dry-up roller to remove water contents from the spread bundles Tw in wet condition discharged from the yarn passage hole h of the portion 34.

(0046)

(APPARATUS EXAMPLE 11)

Figure 18 shows an apparatus example 11 used for the method of producing a spread multi-filament bundle according to the above third embodiment. In this example, a diametrically enlarged waterproof tube type prolonged along the feeding course of the respective bundles is adopted for the fluid

flowing spreader 3, which enlarged tube is segmented into the respective fluid flowing portions 31 through 34 with an interval between them. This is the sole difference between this example and the apparatus example 10, and the other structural arrangement hereof is the same as that of the apparatus example 10. In comparison with the apparatus example 10, the apparatus hereof is done with the sole circulation pump 3a and the sole flow rate regulation valve 3b so that the manufacturing cost of the apparatus is reduced and its operation becomes simplified (0047)

The preferred embodiments of the invention are substantially described above, to which the invention is not limited, but may be modified into various manners within the scope of the accompanying patent claims. For instances, the following modifications also belong to the technical scope of the invention.

- (1) In the aforementioned second and third embodiments and the apparatus examples 2 through 11, it is exemplified that the creel 1 is provided with three yarn suppliers, but as many suppliers as desired may be provided to put as many bundles under treatment.
- (2) In the first through third embodiments and the apparatus examples 1 through 11, a bending degree control bar 36 disposed inside the respective fluid flowing portions is of a circular rod type, but a circular rod member with its middle portion bulged like an entasis shape may be adopted.
- (3) In the above-mentioned apparatus example 6, a hot fan heater 7 is disposed opposite to the respective fluid flowing portions, but an ultrasonic oscillator or a far-infrared radiation device may be adopted instead.
- (4) In the aforementioned apparatus example 4, a linearly pressing mechanism 6 of back-and-forth press roller type is provided between the guide rollers 21 and the guide roller 35 situated at the entrance side of the foremost fluid flowing portion 31 while in the above apparatus example 5, the respective guide rollers 35 disposed on an

entrance side and an exit side of the respective fluid flowing portions 31 through 34 to keep the respective bundles in a certain elevation level are arranged as a multi-filament bundle friction mechanism M such that they move back and forth widthwise with regard to the moving course of the respective bundles. However, an apparatus having both such mechanisms 6 and M is also adoptable.

- (5) In the aforementioned third embodiment, it is exemplified that hot water of 80 degrees Centigrade is used for a fluidal resistance against the bundle Tm, but cold water or warm water may be adopted instead. Further, spreading action is brought into effect by use of liquid-gas two phase flow such as air bubbles in which air bubbles collide with the monofilaments of the respective bundles so as to be broken into particulate bubbles, which bubbles flow through adjacent monofilaments of the respective bundles which are slackened by such collision so as to bring spreading action into effect.

(0048)

(EFFECT)

As described with the above concrete examples, the method of producing a spread multi-filament bundle and an apparatus used in the same according to the invention adopt such mechanism as feeding a number of multi-filament bundles parallelwise in the same plane and with the same velocity from the creel; passing the respective bundles as fed through a plurality of fluid flowing portions disposed along the feeding course of the respective bundles to subject the respective bundles to fluidal resistance so as to bend the respective bundles in passage towards the direction to which a fluid flows and flowing the fluid between any adjacent monofilaments of the respective bundles, the bonding of which monofilaments is slackened due to such fluidal resistance, which mechanism enables a widely spread multi-filament bundles sheet with the fringe side monofilaments of any adjacent spread bundles tangentially and parallelwise aligned with a uniform density to be produced with

high efficiency.

(0049)

According to the invention, such multi-filament bundle of higher strength as carbon fibers, glass fibers, ceramic fibers, polyoxymethylene fibers, aromatic polyamide fibers being bundled is widely spread with high efficiency in a space-saving manner by use of such a structurally simplified apparatus as essentially consisting of a creel, a multi-filament bundle supplier and a fluid flowing spreader comprising a plurality of fluid flowing portions so that the production cost of a spread multi-filament bundles sheet as obtained is reduced while the products themselves are of better quality.

(0050)

The invention is by far advantageous over the prior art references 1 and 2 as referred to above, so that the industrial applicability of the invention is very high.

(BRIEF DESCRIPTION OF THE DRAWINGS)

Figure 1 is a side view of an apparatus example 1 used for the method of producing a spread multi-filament bundle according to the first embodiment.

Figure 2 is a plan view of the apparatus 1 as shown in Figure 1.

Figure 3 is a side view of an apparatus example 2 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 4 is a plan view of the apparatus example 2 shown in Figure 3.

Figure 5 is a side view of an apparatus example 3 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 6 is a plan view of the apparatus example 3 as shown in Figure 5.

Figure 7 is an enlarged view of the internal structure of the fluid flowing spreader used in the apparatus example 3.

Figure 8 is a sectional view taken along A-A line of figure 7.

Figure 9 is a side view of an apparatus example 4 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 10 is a plan view of an apparatus example 5 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 11 is an enlarged plan view to show the interconnection among the guide rollers, the crank motor, the crank arm and the linkage system comprising a multi-filament bundle friction mechanism of the apparatus example 5 as shown in Figure 10.

Figure 12 is an explanatory view to show the mechanism by which the back-and-forth motion converted from the rotational motion of the crank motor is transmitted to the respective guide rollers.

Figure 13 is a side view of an apparatus example 6 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 14 is a side view of an apparatus example 7 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 15 is a side view of an apparatus example 8 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 16 is a plan view of an apparatus example 9 used for the method of producing a spread multi-filament bundle according to the second embodiment.

Figure 17 is a side view of an apparatus example 10 used for the method of producing a spread multi-filament bundle according to the third embodiment.

Figure 18 is a side view of an apparatus example 11 used for the method of producing a multi-filament bundle according to the third embodiment.

## ABSTRACT

### (ISSUE)

A method of producing a spread multi-filament bundle and apparatus used in the same are provided, by which such multi-filament bundles as any kinds of fibers of higher strength being bundled are widely spread with high efficiency in a space and cost-saving manner so as to be produced into a high-quality spread multi-filament bundles sheet with which even a fused thermoplastic resin of higher viscosity can be smoothly and uniformly impregnated.

### (MEANS TO SOLVE ISSUE)

The respective multi-filament bundles as fed parallelwise in the same plane and with the same velocity are passed in suspension through a plurality of fluid flowing portions disposed along the feeding course of the respective bundles, during which the fluid flows through an interstice between adjacent monofilaments.

### (REFERENCED DRAWING)

Figure 1